A comparison between different methods for the assessment of airborne sound insulation in construction elements

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Summary

The experimental assessment of the acoustic performance of materials and construction elements is particularly relevant in the development process of new solutions. Different laboratory methodologies are available for the analysis of airborne sound insulation, making use of differently sized samples, and with different requirements in terms of laboratory facilities. In an expedite manner, it is possible to use an impedance tube to determine the transmission loss of circular samples using samples of the material to be characterized with reduced dimensions. On the other hand, using larger laboratory equipment, such as reverberant acoustic chambers, it is possible to determine the sound insulation of samples with more realistic and representative prototypes. As it is easily recognized, the time spent and resources used in these evaluations are substantially higher, although the acoustic behavior is closer to the real. Thus, this work aims to compare different methodologies for characterizing the airborne sound insulation of construction elements, highlighting the main advantages and disadvantages of the various processes and analyzing the main limitations detected.

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1. Introduction

Given the increasing requirements related to acoustic comfort in buildings, both in terms of regulations and from the standpoint of the end-user, there has been an increasing need to develop more efficient products for acoustic insulation.

The experimental evaluation of the acoustic performance of materials and construction elements is fundamental to the choice of components and characterization of new solutions. The acoustic performance of building materials and systems, and in particular its airborne sound insulation, can be analyzed in the laboratory, using different methodologies, such as tests in reverberant acoustic chambers [1-4] and transmission loss tests in an impedance tube [5,6]. These methodologies differ in the dimensions of the samples to be analyzed and requirements of equipment and laboratory facilities. While in the case of transmission loss evaluation in an impedance tube small circular specimens may be used, providing a preliminary expedite characterization of the solutions, the tests using acoustic chambers require much larger samples, but typically provide more realistic results, although at the expense of mobilizing more significant resources and requiring longer times for specimen installation and testing.

Thus, with the objective of comparing three experimental methodologies to assess the airborne sound insulation, a campaign of tests was performed in the laboratory facilities of ITeCons (Institute for Research and Technological Development in Construction Sciences) [7,8] over a set of specimens with different multilayer configurations. A total of three test methodologies have been used: tests in reverberant acoustic chambers on specimens with standard dimensions; tests in reverberant acoustic chambers using smaller samples; and testing in impedance tube using small circular samples.

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In this paper, we first present the test methodologies used and laboratory equipment that formed the basis of this study. Then, the materials tested are described, and the results obtained briefly explained. Finally, some final conclusions regarding the obtained results are presented.

2. Testing methods and equipment

With the aim of comparing different experimental methodologies for evaluation of airborne sound insulation, experimental tests were performed in the laboratory facilities of ITeCons. The adopted methodologies were: test in reverberant acoustic chambers with samples of standard dimensions (methodology 1); test in reverberant acoustic chambers on specimens of small size (methodology 2); test in impedance tube using samples with circular cross section of small dimensions (method 3).

2.1 Method 1 – Measurement in reverberant chambers

The evaluation of airborne sound insulation of materials and construction elements can be carried out in the laboratory, in reverberant acoustic chambers with diffuse sound field, according to procedures specified in ISO 10140-1: 2010 [1], ISO 10140- 2: 2010 [2] and ISO 10140-4: 2010 [3], in the frequency range from 100 Hz to 5000 Hz (in 1/3 octave bands). The test is carried out in the laboratory in accordance with the normative documents stated above; the airborne sound reduction index, R_w, and related terms of spectral adaptation (C and C_{tr}), can then be determined according to ISO 717-1: 2013 [9]. Briefly, the test follows the next steps: the sound level is recorded in the source room (for 2 omnidirectional sound source positions) using a rotating microphone; simultaneously, the noise level in the receiving chamber is also recorded using a similar microphone; background noise is then evaluated in the receiving room; finally, the reverberation time at the receiving room is also evaluated. In a standardized airborne sound insulation test, the tested specimens should exhibit an area of approximately 10 m^2. Although smaller sizes may be adopted in the case of building elements (such as doors, etc), testing under such conditions must follow additional requirements.

Since in the present work building elements (with an area significantly smaller than 10m^2) are tested, special care was taken when preparing the wall separating the two chambers. This separating wall was thus built (following the relevant standards) as a double wall with a thickness of 400 mm, each of the panels being composed of heavy blocks (with a mass higher than 1800 kg/m^3) finished with mortar on the outer faces. The air gap between panels was filled with high-density mineral wool, and additional care was taken in order to completely seal all possible openings.

These tests were carried out in the horizontal acoustic chambers of ITeCons (Figure 1) [7,8].

2.2 Method 2 – Measurement in reverberant chambers using small sized samples

In the research and development stage of new products, it is is sometimes desirable to perform sound insulation tests making use of smaller sized, non-standard samples. Although the complete test procedure does no longer strictly conform to the test standard, and the obtained results do not completely reproduce the full behaviour of the solution, using smaller samples can still be useful to perform direct comparisons between different

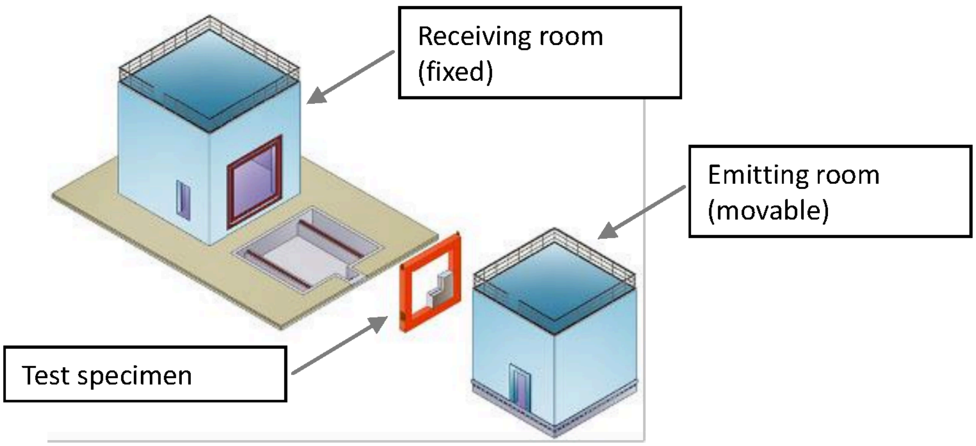


Figure 1. Schematic representation of the acoustic chambers used in the tests.

alternatives and to support development options, during the R&D stage. In fact, the smaller production costs and the simpler installation requirements of those smaller samples can make this a quite attractive option.
For this simpler configuration, the test procedure follows exactly the same steps described in the standards for the Method 1, but specimens with 1.25 m x 1.5 m are used.

2.3 Method 3 – Transmission Loss measured in impedance tube

The Transmission Loss (TL) is a parameter obtained in impedance tube that allows characterizing materials or systems solutions in terms of their capacity to attenuate sound transmission between two spaces [5,6]. The test uses a more expedite methodology, when compared to the Methods 1 and 2, with circular samples of small dimensions. The test is performed in an impedance tube, and the allowed frequency range depends on the diameter of the samples, on the length of the tube and on the position/spacing between the microphones used for sound acquisition. In this work, we used samples with a circular cross-section with a diameter of 100 mm, that allowed evaluating the TL in the frequency range between 100 Hz and 1250 Hz .

The test was performed using a metallic impedance tube with circular cross-section, including a sample holder placed between two segments of the tube. In each of the segments (on each side of the sample), two pressure transducers (microphones) are positioned, as illustrated in Figure 2. The test specimen is placed inside the sample holder, with special care so that adequate sealing is provided, but not allowing an excessivelly stiff connection between the sample and the tube. An acquisition system (pulse, from Bruel & Kjaer) is used for signal recording and processing, also making use of specialized software. The two loads method is used, which requires the alternating use of two different termination conditions at the end of the tube (opposing to the sound source). The test is subdivided into two phases, one for each type of termination. In each of them, the sound field generated by the speaker, placed in one of the ends of the impedance tube and emmiting sound with uniform spectral energy content across the frequency range (white noise), consisting of incident plane waves, is evaluated at the four microphones. The TL is then estimated by post-processing the acquired results.

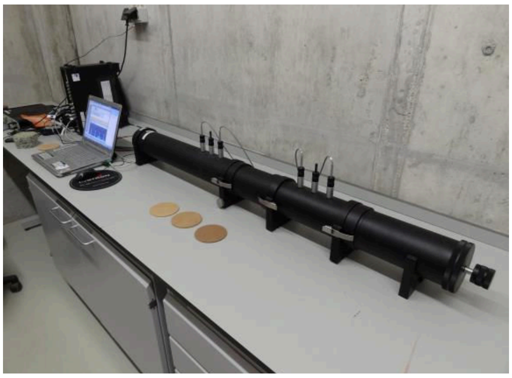


Figure 2. Test equipment (impedance tube and microphones) used for the TL evaluation.

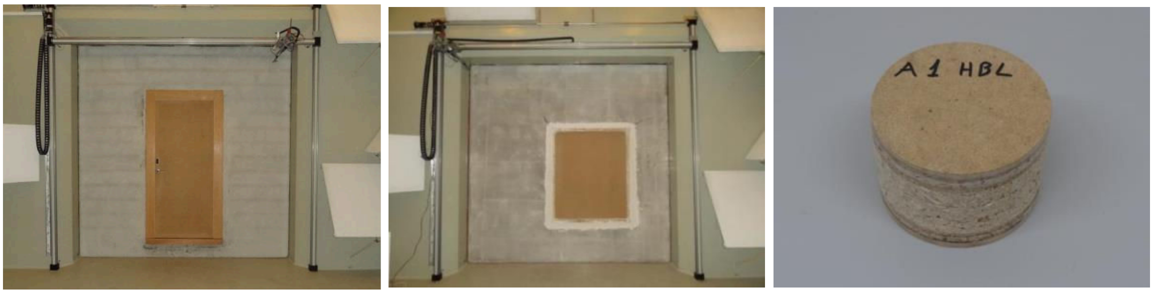
3. Tested samples and materials

In this work several samples with multilayer composition were tested, at the laboratory facilities of ITeCons, using the three different experimental methodologies previously presented. Table I displays some of the physical characteristics of the tested samples. These samples, resulting from the several layers of different materials, in particular MDF, Platex, wood chipboard, synthetic foams, acoustical membranes and steel. Two groups of samples were tested. The first group comprises samples with smaller thickness and smaller surface mass (Group I), and samples in this group are identified with the prefix “P”. The second group (Group II) includes thicker samples with higher surface mass (the prefix “A” is used).

Table I. Physical characteristics of the samples.

Group	*Ref.*	*Thickness (mm)*	*Surface mass (kg/m^2)*
I	P1	54.4	35.9
	P2	40	34.3
	P3	40	32.0
II	A1	71	46.0
	A2	71	46.0
	A3	61.4	40.4

In the scope of the present work, the tests performed in the laboratory were based on a standard configuration, corresponding to a building door with dimensions of 1.9 m x 0.9 m, and with different internal structures. Smaller sized samples with 1.5 m x 1.25 m were used for the Method 2, and circular samples with a diameter of 100 mm were used for Method 3.The same internal



a) b) c)

Figure 3. Schematic representation of the acoustic chambers used in the tests: a) full-size sample; b) small-sized sample; c) circular sample tested for TL.

structure was analyzed for each of the three methods. Figure 3 illustrates some of the tested samples.

4. Results and discussion

In a first approach, tests were conducted in order to assess the differences between the two non-standardized approaches, trying to better understand if significant differences were registered. Two groups of specimens were tested in the impedance tube (Method 3) and in reverberant acoustic chambers, on specimens of small dimensions of 1.5 x 1.25 m (Method 2). Figure 4 illustrates the corresponding results. Comparing the results obtained using these two methods in the frequency range of 100 Hz to 1250 Hz, it is seen that for the samples "P" (thinner and with amller surface mass) the results obtained using the impedance tube (Method 3) are slightly higher, although the curves of the two methods follow very similar trends (Figure 4a)). As for the samples of type "A" (heavier), it can be observed that the curves obtained using the two methods follow very similar patterns throughout the frequency range of interest, and thus with similar acoustic performances being determined in both cases (Figure 4b)). In summary, it is observed that for the tested specimens, the results obtained in the impedance tube seem to be indicative of an upper limit of sound insulation to airborne sounds for lighter specimens ("P") and a lower limit of the sound insulation for heavier test specimens ("A"). It is also interesting to note that the results evaluated using Method 3 do not reveal the insulation dip that occurs at the lower frequencies when Method 2 is used. This dip is possibly related to a specific dynamic behavior of the larger specimens (such as the natural modes of the panels), which indeed do not occur when the small circular specimens are used in the tests.

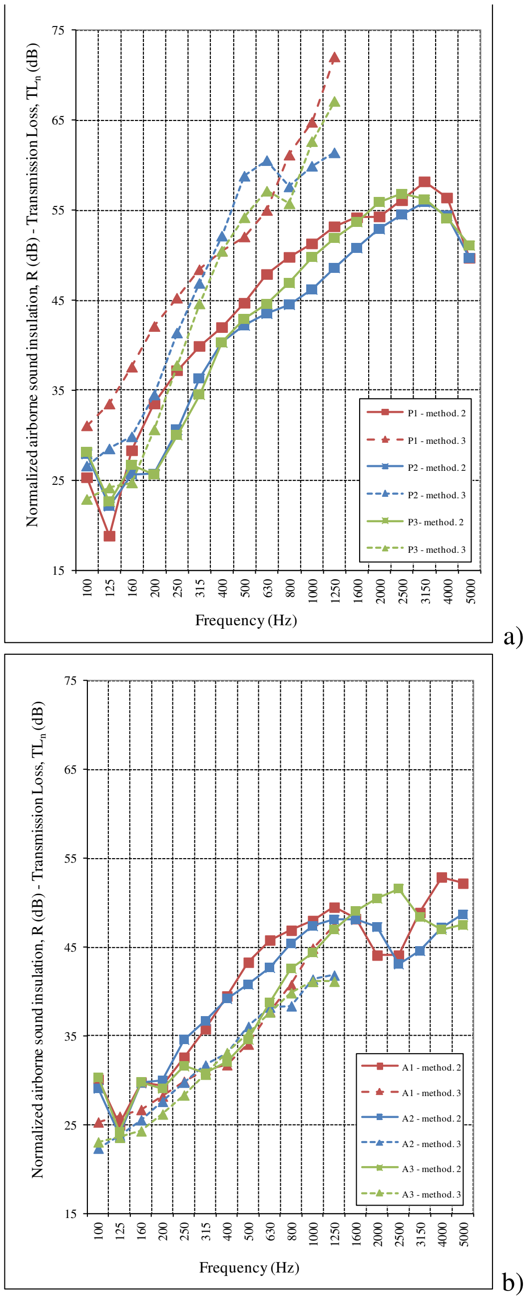


Figure 4. Comparison between Method 2 and Method 3: a) results for specimens of type "P"; b) results for specimens of type "A".

After the initial comparison between Methods 2 and 3 for the 6 specimens, full scale prototypes were produced (with dimensions of 2.0 m x 0.9 m) and tested using Method 1. Although the prototypes consisted of interior doors, including all necessary additional devices, care was taken during their setup in the laboratory so as to avoid any leaks that may occur in small opening (mostly at the bottom). Thus, after an initial test in standard conditions, a second test was performed in which adequate seals were applied to the test specimens in order to minimize the influence of weak spots. Test specimen A1 was selected to illustrate the results obtained in the scope of the present paper, and the corresponding sound insulation curves are illustrated in Figure 5, including all three testing methods.

Observing the results obtained in the laboratory, it can be seen that in samples with composition A1 (Figure 5), the sound insulation curves obtained in a reverberation chamber (Methods 1 and 2) are very close to each other and have similar progress in the range of low frequencies. Comparing the case of the standard door tested with Method 1, with the results from Method 2, it can be observed that very significant differences occur above 400 Hz; indeed, after this frequency the effect of the lack of adequate seals in the full-scale door is quite strong, and leads to an evident performance loss. If the results obtained for the fully sealed door

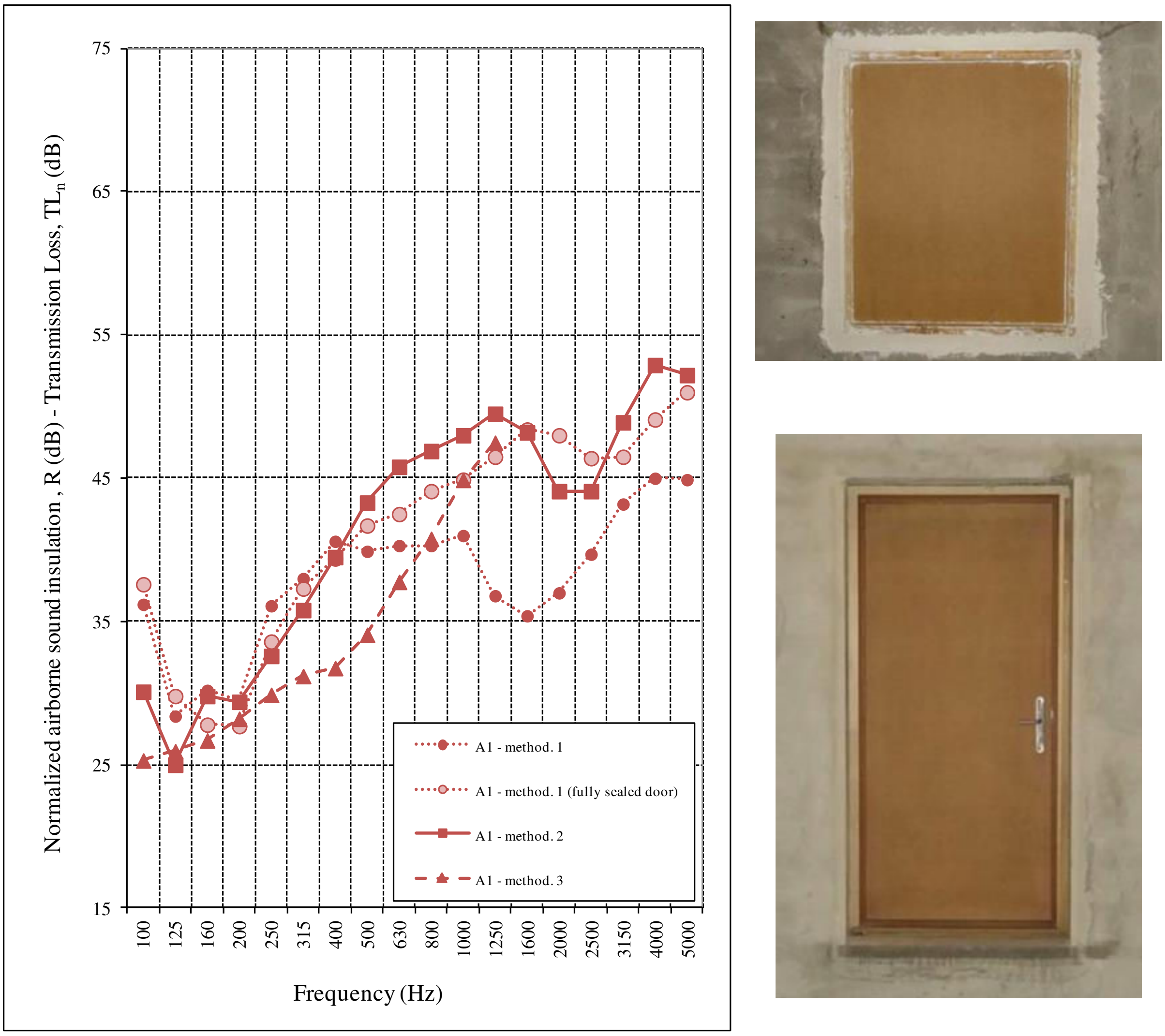


Figure 5. Results obtained for the specimen A1 using Methods 1, 2 and 3. Right column illustrates the test conditions for Methods 1 and 2, performed in reverberant chambers making use of differently sized samples.

are used for comparison, a much closer match between Methods 1 and 2 occurs, and similar behaviours are obtained; this proximity between the two results indicates that the smaller sized sample can reasonably represent an adequately sealed door, although with some differences still occurring. When these results are compared with those obtained using Method 3, using an impedance tube, it can be seen that larger differences are registered, as already identified in Figure 4.

5. Conclusions

In the present work, the results obtained in the laboratory for three experimental methodologies to analyze the airborne sound insulation of construction elements were presented and compared. The test methods were: test in reverberant chambers using full-size samples; test in reverberant chambers using smaller samples; TL evaluation in impedance tube. The test specimens consisted of multilayered solutions, with different materials: MDF, Platex, wood chipboard, synthetic foams, acoustic membranes and steel.

Comparing the results of samples tested using the different methods, it was found that significant differences are registered between TL results and sound reduction results evaluated in reverberant chambers. Indeed, it was found that the TL results do not give a reliable quantitative indication of the acoustic performance of construction solutions, although they may be of good use in a qualitative comparison between different specimens. It was also found that depending on the characteristics of the tested specimens, the TL results may give either an underestimation or an overestimation of the performance of larger sized samples, and no definitive rule could be established regarding the quantitative relation between these results and those evaluated in reverberant chambers.

Comparing the two approaches in reverberant chambers for the analysis of airborne sound insulation, it was found that the size and proportions of the specimen were less important than the quality of the applied seals along the contour of the specimen; when adequate care was taken in the installation of the specimen and in the application of those seals, good correlation between results was found.

Acknowledgement

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